APTD-0817

PB 210 564

STATE OF HAWAII
AIR POLLUTANT EMISSION INVENTORY

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service

NATIONAL TECHNICAL
INFORMATION SERVICE

The APTD (Air Pollution Technical Data) series of reports is issued by the Office of Air Programs, Environmental Protection Agency, to report technical data of interest to a limited number of readers. Copies of APTD reports are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - as supplies permit - from the Office of Technical Information and Publications, Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22151.

Office of Air Programs Publication No. APTD-0817

BIBLIOGRAPHIC DATA SHEET	1. Report No. APTD-0817	2.	3. Recipient's Accession No. PB-210 564
4. Title and Subtitle State of Hawaii Air Pollutant Emission Inventory			5. Report Date January 1970 6.
7. Author(s) Clyde B. Morita			8. Performing Organization Rept. No.
9. Performing Organization Name and Address U. S. Department of Health, Education, and Welfare National Air Pollution Control Administration Division of Air Quality and Emission Data Durham, North Carolina			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address Same			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts The sources and emissions of air pollutants are outlined. Estimates are provided of total emissions of oxides of sulfur, oxides of nitrogen, hydrocarbons, carbon monoxide and particulate matter. The emissions of these pollutants are delineated with respect to source type, season of the year, and by their geographical distribution within the area. The current level of emissions and status of their control was also determined. The general procedure for these surveys is based on the rapid survey technique. Emissions for the most part are estimated using various indicators of pollutant emissions and average emission factors that are related to these. The estimated annual emissions of the five surveyed pollutants in the State of Hawaii are 60 thousand tons of sulfur oxides, 71 thousand tons of particulate matter, 400 thousand tons of carbon monoxide, 76 thousand tons of hydrocarbons, and 45 thousand tons of oxides of nitrogen. The major source of pollutants in the urbanized area of the State is the automobile. The power plants and solid waste disposal sites can cause localized problems. In the rural areas, the predominant source of emissions is that associated with the production of cane sugar.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Exhaust emissions
Inventories
Sulfur oxides
Nitrogen oxides
Hydrocarbons
Carbon monoxide
Particles
Seasonal variations
Motor vehicles
Steam electric power production
Refuse disposal
Incinerators
Combustion

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 13B

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited	UNCLASSIFIED	69
	20. Security Class (This Page) UNCLASSIFIED	22. Price $3.00

STATE OF HAWAII
AIR POLLUTANT EMISSION INVENTORY

Clyde B. Morita

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
Consumer Protection and Environmental Health Service
National Air Pollution Control Administration
Division of Air Quality and Emission Data
Durham, North Carolina
January, 1970

II

ACKNOWLEDGMENTS

The National Air Pollution Control Administration acknowledges with appreciation the many contributions of cooperating agencies in the compilation of this report. In particular, we are grateful for the use of data and personnel assistance furnished by the following agencies:

1. Hawaii State Department of Health, Air Sanitation Branch
2. Hawaii State Department of Transportation

PREFACE

This report, which presents the emission inventory of the State of Hawaii, is another in a series of studies outlining the sources and emissions of air pollutants for major metropolitan areas in the country. These reports provide estimates of total emissions of oxides of sulfur, oxides of nitrogen, hydrocarbons, carbon monoxide and particulate matter. The emissions of these pollutants are delineated with respect to source type, season of the year, and by their geographical distribution within the area. These surveys are also intended to determine the present level of emissions and status of their control.

The general procedure for these surveys is based on the rapid survey technique.[1] The study area is divided into grid zones that serve as the basis for locating sources and reporting their emissions. All sources of pollutants are divided into two subgroups—point and area sources. Sources that emit large quantities of air pollutants are considered individually and located specifically within the area. This group generally includes about fifty to one hundred sources such as large industries, power plants, and central refuse burning facilities. The remaining multitude of sources are considered collectively as area sources and their emissions are reported as totals for grid zones. This category includes motor vehicles, home heating, smaller industries, on-site refuse burning, etc.

Emissions for the most part are estimated using various indicators of pollutant emissions and average emission factors that are related to these. Information and data are collected on fuel consumption, refuse burning rates, vehicle miles of travel, as well as various production data. These are then translated into emission estimates by use of average emission factors.[2] These factors, for the most part, represent average emission rates for a particular industry or fuel type.

Because of the inherent difference in types of equipment, operating rates, control equipment, and efficiency of operation among the plants and fuel users within a given category, the application of the emission factors to any individual plant or even a smaller number of similar plants or processes may result in a discrepancy between the actual and the estimated emissions. However, the estimates of total pollutants from all sources in the study area should be reasonably accurate since the emission factors are based on average conditions.

TABLE OF CONTENTS

	Page
Introduction	1
Summary of Results	2
Study Area	5
Topography and Climate	5
Grid Coordinate System	10
Emissions by Source Category	12
Transportation	12
Fuel Combustion in Stationary Sources	21
Solid Wastes Disposal	24
Industrial Process Losses	27
Evaporative Losses	31
Agriculture	32
Emissions by Jurisdiction	38
Emissions by Grid	46
Contribution of Point Sources	46
Emission Densities	53
References	59
Appendix	60

LIST OF TABLES

Table		Page
1	Summary of Air Pollutant Emissions in the State of Hawaii, 1968	4
2	Population and Area Characteristics for the State of Hawaii	8
3	Air Pollutant Emissions from Transportation Sources in the State of Hawaii	14
4	Motor Vehicles Travel Characteristics	15
5	Air Pollutant Emissions from Motor Vehicles and Vessels, 1968	17
6	Aircraft Activity and Air Pollutant Emissions in the State of Hawaii, 1968	19
7	Fuel Consumption by Vessels in the State of Hawaii, 1968	20
8	Fuel Consumption in Stationary Sources, 1968	22
9	Fuel Consumption and Air Pollutant Emissions from Steam-Electric Utilities, 1968	23
10	Air Pollutant Emissions from the Combustion of Fuels in Stationary Sources, 1968	25
11	Solid Wastes Disposal by County, 1968	26
12	Air Pollutant Emissions from Solid Wastes Disposal, 1968	28
13	Air Pollutant Emissions from Industrial Process Losses on the Island of Oahu, 1968	30
14	Hydrocarbon Emissions from Evaporative Losses, 1968	30
15	Distribution of Crop Acreage by County, 1968	33
16	Sugar Production by County, 1968	33
17	Air Pollutant Emissions from Agricultural Operations, 1968	36
18	Air Pollutant Emissions from Agricultural Fuel Combustion	37
19	Summary of Air Pollutant Emissions in Hawaii County, 1968	41
20	Summary of Air Pollutant Emissions in the City and County of Honolulu, 1968	42

Table		Page
21	Summary of Air Pollutant Emissions in Kauai County, 1968	43
22	Summary of Air Pollutant Emissions in Maui County, 1968	44
23	Relative Contribution of Each County to Total Air Pollutant Emissions, 1968	45
24	Summary of Air Pollutant Emissions from Points Sources on the Island of Oahu, 1968	48
25	Summary of Air Pollutant Emissions by Grid on the Island of Oahu, 1968	49

LIST OF ILLUSTRATIONS

Figure		Page
1	State of Hawaii	6
2	Island of Oahu	7
3	Population Density Map of the Island of Oahu, 1968	9
4	Grid Coordinate System for the Island of Oahu	11
5	Location of Point Sources on the Island of Oahu	47
6	Sulfur Oxides Emission Density Map of the Island of Oahu	54
7	Particulate Matter Emission Density Map of the Island of Oahu, 1968	55
8	Carbon Monoxide Emission Density Map of the the Island of Oahu, 1968	56
9	Hydrocarbon Emission Density Map of the Island of Oahu, 1968	57
10	Nitrogen Oxides Emission Density Map of the Island of Oahu, 1968	58

INTRODUCTION

The information and data presented in this report were gathered in cooperation with the Air Sanitation Branch in the Hawaii State Department of Health during a survey conducted in November, 1969. The data obtained is for the most part representative of 1968, and the emission estimates presented herein should be considered as describing the levels and conditions during that year.

The purpose of this study is to establish the magnitude, extent and sources of air pollutant emissions for the State of Hawaii. An immediate use of these data is to provide the basis of the engineering evaluation in the designation of an Air Quality Control Region for the Honolulu area. These data will also be included into a national emission baseline and will provide a basis for future air resource management.

Although this survey includes the entire State of Hawaii, particular emphasis has been placed on the Island of Oahu. Thus, for Oahu, the air pollutant emissions are presented on a grid basis as well as county totals. The emphasis on Oahu is warranted because most of the people and most of the air pollutant emissions are located there.

SUMMARY OF RESULTS

The estimated annual emissions of the five surveyed pollutants in the State of Hawaii are 60 thousand tons of sulfur oxides, 71 thousand tons of particulate matter, 400 thousand tons of carbon monoxide, 76 thousand tons of hydrocarbons, and 45 thousand tons of oxides of nitrogen. The major source of pollutants in the urbanized area of the State is the automobile. The power plants and solid waste disposal sites can cause localized problems. In the rural areas, the predominant source of emissions is that associated with the production of cane sugar.

The breakdown of pollutant emissions by source category for the State is listed in Table 1. The following is a brief summary of pollutant emissions and sources:

Sulfur Oxides — The predominant source of the 60 thousand tons of sulfur oxides emitted annually is the combustion of residual fuel oil in steam-electric utilities for the generation of electricity. The five power plants burning residual fuel oil account for more than 60 percent of the sulfur oxides emissions. Additional stationary fuel combustion sources contribute 13 percent, industrial process losses 11 percent, and agriculture 10 percent of total emissions.

Particulate Matter — Agricultural operations, mainly cane field burning and bagasse incineration, contribute the majority (70 percent) of the 71 thousand tons of particulate matter emitted annually. The next largest source is solid wastes disposal which accounts for nearly 17 percent of particulate

matter emissions. The remaining 13 percent is divided between transportation sources, fuel combustion in stationary sources, and individual process losses.

Carbon Monoxide

Motor vehicles, mainly automobiles, contribute 58 percent of the 400 thousand tons of carbon monoxide emitted. The percentage contribution from motor vehicles is much higher in the urbanized areas since the next highest contributors are agriculture and solid wastes disposal, which account for 23 percent and 15 percent, respectively, of total carbon monoxide emissions.

Hydrocarbons

The annual emissions of 76 thousand tons of hydrocarbons are distributed between the various source categories. The three largest sources are motor vehicles (40 percent), solid wastes disposal (28 percent), and evaporative losses (21 percent), which collectively account for 89 percent of the hydrocarbon emissions.

Nitrogen Oxides

Motor vehicles and steam-electric utilities are the predominant sources of the 45 thousand tons of nitrogen oxides emitted annually. They contribute 28 percent and 27 percent, respectively, of total emissions. Other transportation and stationary fuel combustion sources account for an additional 14 percent, while solid wastes disposal, mainly open burning, contributes 17 percent of total nitrogen oxides emissions.

TABLE 1 SUMMARY OF AIR POLLUTANT EMISSIONS IN THE STATE OF HAWAII, 1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation	3,000	2,600	248,000	34,000	15,000
Motor Vehicles	860	1,500	233,000	30,100	12,700
Aircraft	N	800	14,700	3,300	1,300
Vessels	2,100	270	350	230	680
Fuel Combustion in Stationary Sources*	44,000	2,000	60	500	16,000
Residential, Commercial, Institutional	2,600	300	23	21	1,400
Industry	5,100	460	30	100	2,600
Steam-Electric	36,100	1,200	4	380	12,000
Solid Waste Disposal	900	12,000	60,000	21,000	7,800
Open Burning	700	11,000	59,000	21,000	7,600
Incineration	180	660	1,300	70	190
Industrial Process Losses	6,400	4,400	40	1,100	1,200
Evaporative Losses	N	N	N	16,000	N
Agriculture	5,700	50,000	91,000	3,000	4,800
TOTAL	60,000	71,000	400,000	76,000	45,000

N = Negligible

* Emissions from agricultural fuel combustion included in agriculture column.

STUDY AREA

The Study Area for the State of Hawaii Air Pollutant Emission Inventory consists of four counties which include the eight major islands in the State of Hawaii (See Figure 1). The islands are located approximately 2,600 miles southwest of Los Angeles. Kalawao County, the smallest of the five counties in the State, is actually part of the island of Maui. For the purposes of this report, the emissions from Kalawao County are included in the Maui County totals. Maui County includes the islands of Maui, Molokai, Lanai and Kahoolawe. Kauai County includes the islands of Kauai and Niihau, whereas Honolulu and Hawaii Counties are contiguous with their respective islands.

The island of Oahu (Figure 2) is the major island population wise, and contains 83 percent of the State population of 824,800[3]. Table 2 lists the population data by county. Oahu has had a tremendous rate of population increase since 1960. Oahu ranks as one of the fastest growing metropolitan areas in the country, with a 35 percent increase in 8 years. Figure 3 shows the geographical distribution of population on Oahu. Most of the population is concentrated in the southern part of the island in and around the city of Honolulu.

TOPOGRAPHY AND CLIMATE

The topography of the Hawaiian Islands is marked in contrasts. These islands contain high mountains and mountain ranges, broad valley lands, rain forests, sandy beaches, and plunging cliffs. Almost any type of land form can be found in the Hawaiian archipelago.

Hawaii's climate is almost ideal throughout the year with an average annual temperature ranging from 72 degrees in February to 79 degrees in August. Thus, there are no degree-days and the subsequent space heating requirements except for some communities at the higher

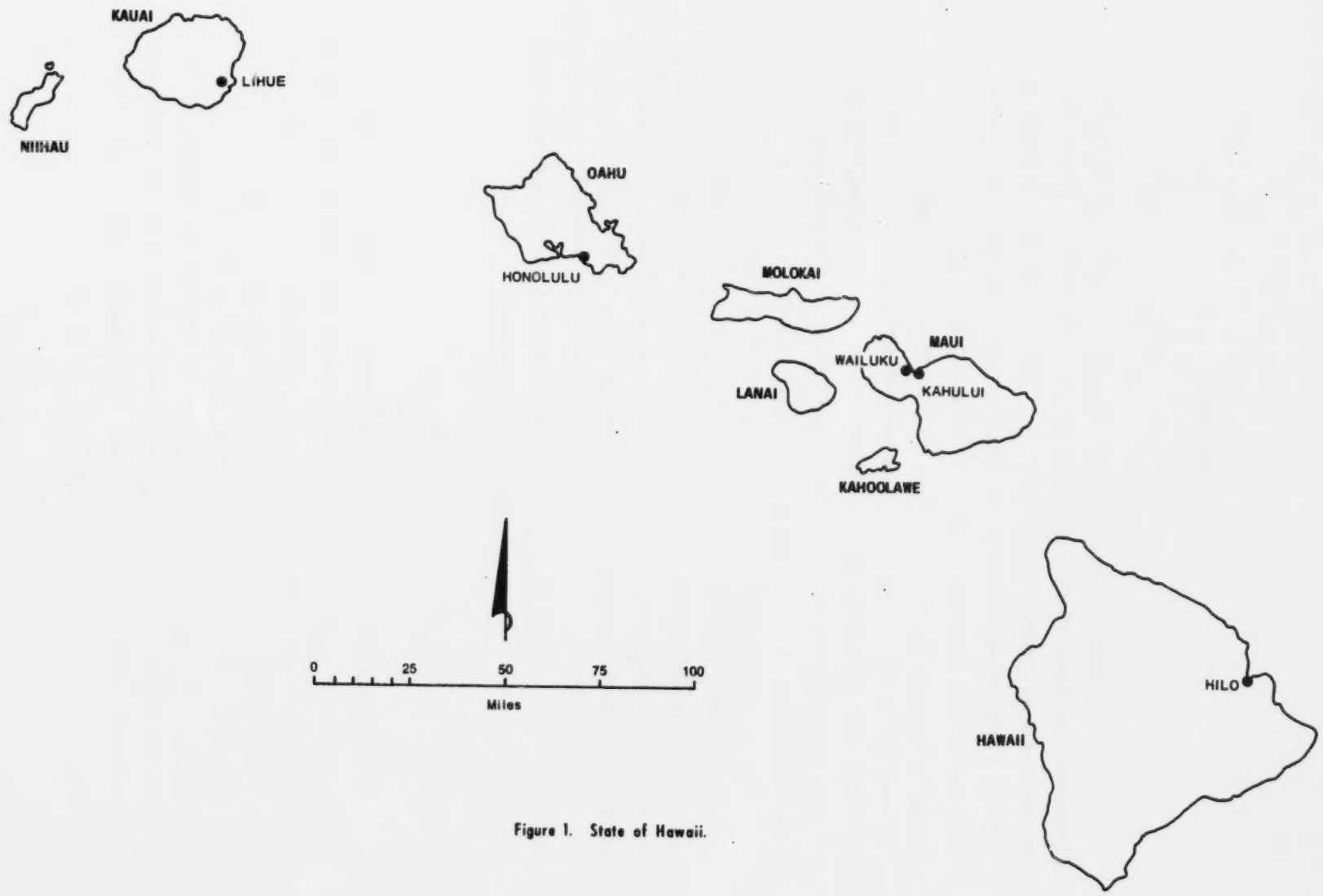

Figure 1. State of Hawaii.

Figure 2. Island of Oahu.

TABLE 2 POPULATION AND AREA CHARACTERISTICS FOR THE STATE OF HAWAII*

County	Land Area (sq. mi.)	1960 Population	1968 Population	1968 Population Density, People/sq. mi.
Hawaii	4,037	61,300	65,900	16
Honolulu	596	500,400	683,800	1,150
Kalawao	13	280	230	18
Kauai	619	28,200	25,100	41
Maui	1,160	42,600	49,800	43
STATE TOTAL	6,425	632,800	824,800	128

* Estimated resident population

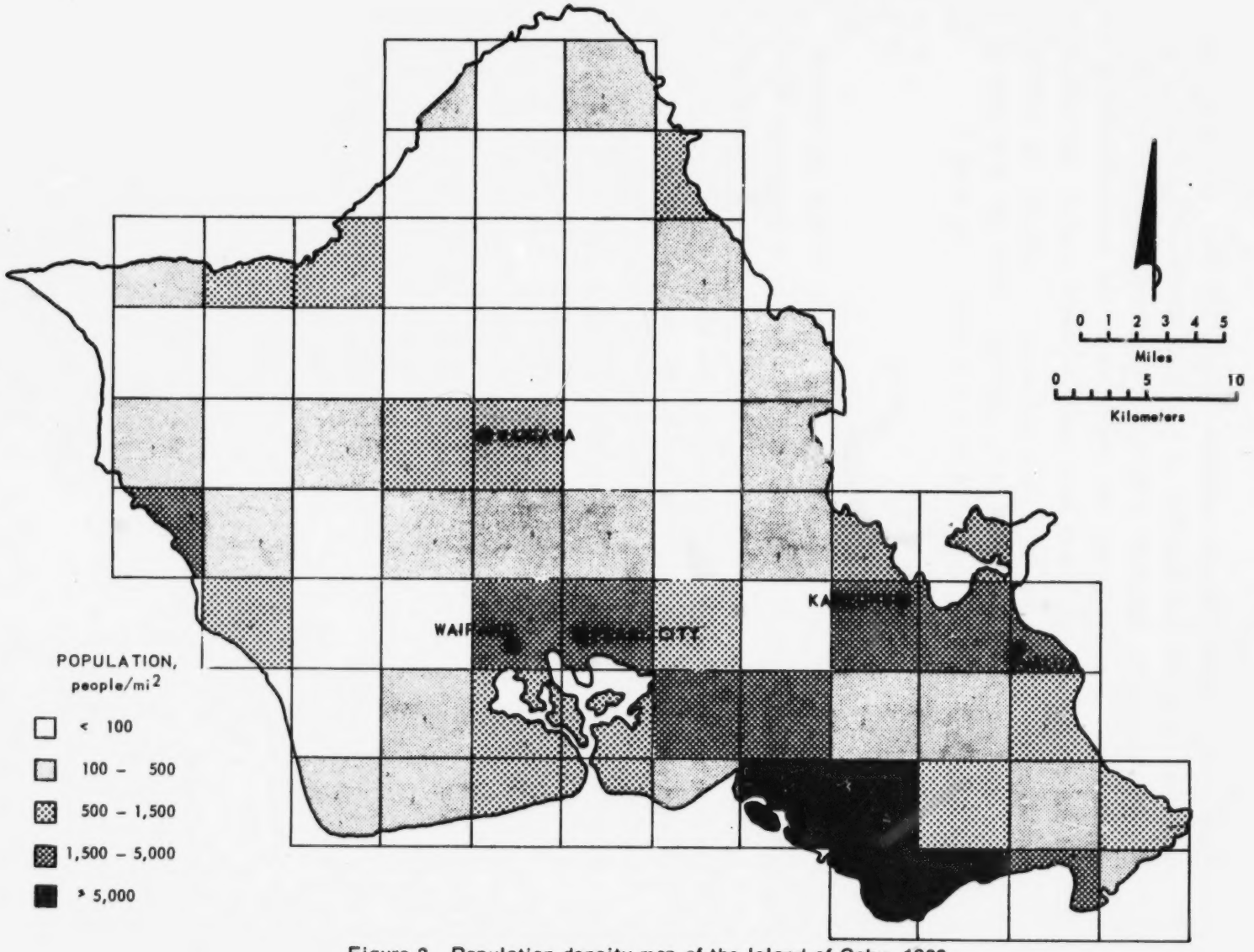

Figure 3. Population density map of the Island of Oahu, 1968.

elevations. Temperature and rainfall vary within the State depending more upon elevation and location rather than season.

Outstanding in Hawaiian climate are the remarkable differences in rainfall over adjacent areas; the sunniness of the leeward lowlands and the persistent cloudiness over mountain peaks nearby; the remarkably equable temperature from day to day and season to season; the persistence of tradewinds from the northeasterly quadrant, where not disrupted by high mountains; and the rarity of severe storms of any kind.[4]

GRID COORDINATE SYSTEM

For the purposes of this survey, the island of Oahu was divided into 73 grids of 25 square kilometers to show the geographical distribution of sources and emissions. The grid system is based on the Universal Transverse Mercator System developed by the United States Army Corps of Engineers. The easting (east-west) and northing (north-south) coordinates are expressed in meters. Only one grid size was used to allow a comparable basis for expressing emissions and densities (Figure 4).

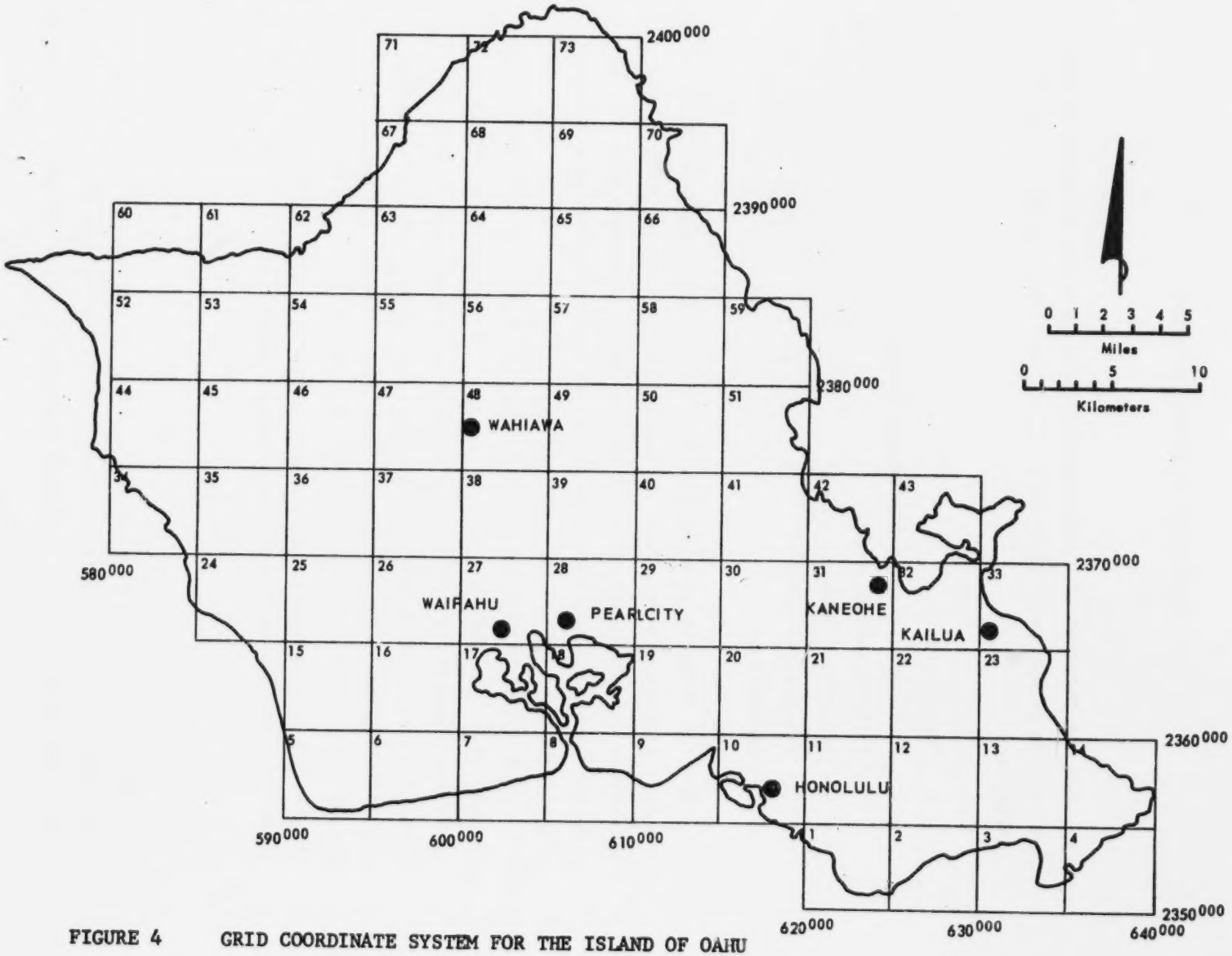

FIGURE 4 GRID COORDINATE SYSTEM FOR THE ISLAND OF OAHU

EMISSIONS BY SOURCE CATEGORY

For the purposes of compiling the basic data and emission estimates, the sources of air pollutants were classified into the following six categories:

1. Transportation
2. Fuel Combustion in Stationary Sources
3. Solid Wastes Disposal
4. Industrial Process Losses
5. Evaporative Losses
6. Agriculture

Each of these categories is considered individually in this section. The data sources and necessary assumptions are presented with further breakdowns of emissions. Some of the estimates are presented only as areawide totals. The section on emissions by jurisdiction summarizes the emissions by source for each county.

Some of the estimates presented herein, especially the industrial process loss category, are partial totals. The lack of emissions factors and appropriate process and control data prevent a complete inventory of all sources and emissions. It should also be recognized that natural sources of emissions, such as volcanoes, salt-spray and natural dusts, have not been included that may at times be significant contributors to the total air pollution problem. The results of this survey should be viewed with these limitations in mind.

TRANSPORTATION

Three types of transportation sources are considered in this survey—motor vehicles, aircraft, and vessels. Motor vehicles, which are the most significant source of air pollutant emissions in this category are further

subdivided according to type of fuel used--gasoline and diesel. Railroad activity in the State is minimal and has not been included in the reporting of emissions.

Table 3 summarized the contribution of transportation sources to air pollutant emissions in the State. Motor vehicles are the predominant transportation source, accounting for 29 percent, 55 percent, 94 percent, 90 percent, and 87 percent of the sulfur oxides, particulate matter, carbon monoxide, hydrocarbons, and nitrogen oxides emissions from transportation, respectively. Vessels, mainly the combustion of residual fuel oil for bunkering purposes, are the predominant transportation source of sulfur oxides.

Motor Vehicles

More than 2.8 billion miles were traveled by motor vehicles in the State in 1968.[5] Ninety-nine percent of the vehicle-miles were attributed to gasoline powered vehicles, mainly automobiles. In the process, 198 million gallons of gasoline and 6.8 million gallons of diesel fuel were consumed for highway purposes. Table 4 indicates that 79 percent of all motor vehicle travel occurs on the island of Oahu.

Approximately 1.5 percent of gasoline is lost through evaporation from the gasoline tanks and carburetor losses resulting in annual losses of about 3 million gallons. It was assumed that the evaporation of diesel fuel was negligible. Since 1963 most new automobiles were equipped with positive crankcase ventilation (PCV) valves that reduce hydrocarbon emissions from the crankcase by about 90 percent. Due to a lag time in the automobile replacement rate, about 20 percent of the automobiles were not equipped with PCV valves.

For the island of Oahu, the vehicle-miles of travel were apportionned onto the respective grids by the use of traffic information (vehicle miles and traffic flow maps) obtained from the Oahu Transportation Study.[6] Vehicle counts were available for about 64 percent of the total

TABLE 3 AIR POLLUTANT EMISSIONS FROM TRANSPORTATION SOURCES IN THE STATE OF HAWAII, 1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Motor Vehicles					
Gasoline					
Exhaust	850	1,130	233,000	17,800	12,000
Evaporation*	N	N	N	11,900	N
Diesel	13	350	200	440	720
Subtotal	860	1,480	233,200	30,100	12,700
Aircraft					
Jet	N	670	760	660	500
Turboprop	N	70	160	60	110
Piston	N	60	13,800	2,580	650
Subtotal	N	800	14,700	3,300	1,260
Vessels					
Small Boats	30	80	300	120	170
Large Boats	2,080	190	50	110	510
Subtotal	2,110	270	350	230	680
GRAND TOTAL	3,000	2,700	248,000	33,600	14,600

N = Negligible

* Includes crankcase emissions

TABLE 4 MOTOR VEHICLE TRAVEL CHARACTERISTICS, 1968

County	Motor Vehicle Registrations			Motor Fuel Consumption 10^3 Gallons		Vehicle-Mile Travel 10^6 Vehicle-Miles		
	Automobiles	Trucks	Total	Gasoline	Diesel	Gasoline	Diesel	Total
Hawaii	27,400	5,970	36,050	18,860	1,210	275	6	281
Honolulu	252,550	23,500	291,940	156,550	4,700	2,235	23	2,258
Kauai	13,530	2,590	17,460	8,860	350	127	2	129
Maui	21,540	4,070	27,960	13,390	560	192	3	195
STATE TOTAL	315,000	36,100	373,400	197,700	6,820	2,840	33	2,870

vehicle-miles traveled on Oahu in 1960.

The vehicle-miles were calculated and placed into the respective grids. The remaining 36 percent of travel was then apportionned by population. The total vehicle-miles for each grid was then updated to the total 2,235 million vehicle-miles traveled on Oahu in 1968.

The resulting emissions from motor vehicles are shown by county on Table 5. Motor vehicles account for 860 tons of sulfur oxides, 1,500 tons of particulate matter, 233,000 tons of carbon monoxide, 30,100 tons of hydrocarbons, and 12,700 tons of nitrogen oxides emitted annually in the State. The majority of these emissions are located on the island of Oahu. Diesel powered vehicles contribute only a small portion of the motor vehicular emissions.

TABLE 5 AIR POLLUTANT EMISSIONS FROM MOTOR VEHICLES AND VESSELS, 1968 (TONS/YEAR)

County	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxide
Hawaii					
Motor Vehicles					
Gasoline	80	110	22,700	2,850	1,170
Diesel	23	63	34	77	130
Vessels	170	25	42	23	60
Honululu					
Motor Vehicles					
Gasoline	670	890	184,000	23,500	9,500
Diesel	68	240	130	300	500
Vessels	1,760	220	280	190	560
Kauai					
Motor Vehicles					
Gasoline	40	50	10,500	1,330	540
Diesel	7	18	11	23	37
Vessels	70	7	9	6	20
Maui					
Motor Vehicles					
Gasoline	60	80	15,900	2,020	820
Diesel	11	30	16	35	60
Vessels	110	17	21	15	40

Aircraft

There are seven major civil airports operating in the State. The Honolulu International Airport is the busiest, accounting for about 64 percent of the total aircraft operations in the State. Table 6 shows that of the 264,000 flights in 1968, 35 percent were jets, 26 percent were turboprop, and 39 percent were piston-powered aircraft.

The breakdown of flights by type of plane in the commercial carrier class was available from the Federal Aviation Administration.[7] Total flights by military and general aircraft were also available.[8] For the purpose of calculating emissions, general aircraft were assumed to be all 2-engine piston powered. Military aircraft were assumed to be 2-engine jets for all local operations, and evenly split between 4-engine turboprops and 4-engine jets for all itinerant operations.

Aircraft activity contributes less than 5 percent of the total emissions of any pollutant in the State. The emissions from aircraft, however, can be a localized problem, especially the visible particulate matter. The contribution of the gaseous pollutants to the total problem should be negligible.

Vessels

Vessels, both large and small, consume about 227 thousand gallons of gasoline, 16.1 million gallons of diesel fuel, and 95.5 million gallons of residual fuel oil in the State.[9, 10] Table 7 shows the distribution of fuel consumption by county and type of vessel. All of the gasoline and diesel fuel consumed by small boats were assumed to be burned close to or within the geographical confines of the Study Area. However, only 10 percent of the diesel and residual fuel oil consumed by large boats (bunkering purposes) were assumed to contribute to the total emissions. The air pollutant emissions from vessels are presented in Table 5. The majority of emissions from vessels are attributable to the combustion of residual fuel oil for vessel bunkering.

TABLE 6 AIRCRAFT ACTIVITY AND AIR POLLUTANT EMISSIONS IN THE STATE OF HAWAII, 1968 (TONS/YEAR)*

County	Total Flights	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Hawaii					
Jet	11,880	60	80	90	50
Turboprop	10,030	11	23	9	16
Piston	22,480	14	3,020	560	140
Subtotal	44,390	85	3,120	660	210
Honolulu					
Jet	63,430	520	570	470	380
Turboprop	38,140	40	90	35	60
Piston	68,460	40	9,180	1,710	430
Subtotal	170,000	600	9,840	2,220	870
Kauai					
Jet	4,960	9	26	36	11
Turboprop	3,710	4	10	3	7
Piston	N.A.	N.A.	N.A.	N.A.	N.A.
Subtotal	8,670	13	36	39	18
Maui					
Jet	12,820	74	80	65	54
Turboprop	15,900	15	35	13	24
Piston	12,210	7	1,635	305	76
Subtotal	40,930	100	1,750	380	150
STATE TOTAL					
Jet	93,100	670	760	660	500
Turboprop	67,800	70	160	60	110
Piston	103,100	60	13,840	2,580	650
TOTAL	264,000	800	14,760	3,300	1,260

N.A. = Not available
* Sulfur oxides emissions from aircraft are negligible.

TABLE 7 FUEL CONSUMPTION BY VESSELS IN THE STATE OF HAWAII
1968, (10^3 Gallons)

County	Gasoline	Diesel Fuel	Residual Fuel Oil
Hawaii			
Small Boats	28.2	157	N
Large Boats	N	1,200	7,500
Honolulu			
Small Boats	179.5	1,144	N
Large Boats	N	12,000	80,000
Kauai			
Small Boats	6.5	14	N
Large Boats	N	600	3,000
Maui			
Small Boats	12.5	100	N
Large Boats	N	900	5,000
State Total			
Small Boats	226.7	1,415	N
Large Boats	N	14,700	95,500

FUEL COMBUSTION IN STATIONARY SOURCES

The most important fuel consumed in the State of Hawaii for heat and power is residual fuel oil. In 1968, residual fuel oil accounted for 48 trillion BTU's or approximately 75 percent of the total energy consumption. As shown on Table 8, 315 million gallons of residual fuel oil, 25 million gallons of diesel fuel, 10 million gallons of distillate fuel oil, 11 million gallons of liquified petroleum gases (mainly propane), and 2.5 billion cubic feet of manufactured gas were consumed in the State.

Fuel combustion in stationary sources has been divided into four user categories—residential-commercial-institutional, industrial, steam-electric utility, and agricultural. Fuel consumption for agricultural operations has been included here, however, the emissions are presented in the Agriculture Section of this report.

Residual fuel oil is consumed to some extent in all four consumer categories, however, steam-electric utilities consume 228 million gallons or 72 percent of the residual fuel oil. Diesel fuel oil is consumed mainly for agricultural purposes, such as operating pumps, generators, and other types of engines. About 60 percent of the diesel fuel is consumed for agricultural purposes. Distillate fuel oil (excluding diesel) is consumed to a limited extent in all categories except steam-electric utilities. Commercial and institutional establishments consume about half of the total distillate fuel oil. Liquified petroleum gases (LPG) and manufactured gas are used mainly as cooking and water heating fuel. No coal is consumed in the State.

There are seven major steam-electric generating plants in the State. These plants consume 228 million gallons of residual fuel oil and 1.8 million gallons of diesel fuel. Table 9 presents the fuel consumption and resultant emissions by plant. There are no existing air pollution control systems on any of these plants. However, in 1969 the Honolulu power generating station was switching from a 1.9 percent sulfur residual fuel oil to a low sulfur fuel oil.

TABLE 8 FUEL CONSUMPTION IN STATIONARY SOURCES, 1968

County	Diesel Fuel Oil 10^3 Gallon	Distillate* Fuel Oil 10^3 Gallon	Residual Fuel Oil 10^3 Gallon	Liquified Petroleum Gases 10^3 Gallon	Manufactured Gas 10^6 cu.ft.
Hawaii					
Residential, Commercial Institutional	N	500	800	3,400	N
Industry	3,400	2,000	N	150	N
Steam-Electric Utility	301	N	14,900	N	N
Agriculture	2,100	320	5,500	110	N
Honolulu					
Residential, Commercial Institutional	3,800	4,240	9,770	4,500	1,170
Industry	3,400	2,000	51,600	200	1,320
Steam-Electric Utility	N	N	202,000	N	N
Agriculture	3,900	580	5,500	210	N
Kauai					
Residential, Commercial Institutional	N	200	300	1,400	N
Industry	300	200	N	60	N
Steam-Electric Utility	308	N	N	N	N
Agriculture	600	100	2,600	30	N
Maui					
Residential, Commercial Institutional	N	280	600	1,630	N
Industry	500	300	N	70	N
Steam-Electric Utility	1,230	N	11,300	N	N
Agriculture	8,300	1,200	10,400	460	N
STATE TOTAL					
Residential, Commercial Institutional	3,800	5,200	11,500	9,840	1,170
Industry	4,600	2,800	51,600	500	1,320
Steam-Electric	1,840	N	228,000	N	N
Agriculture	14,900	2,200	24,000	800	N
TOTAL	25,100	10,200	315,000	10,900	2,490

* Includes Kerosine but excludes diesel fuel oil.

N = Negligible

TABLE 9 FUEL CONSUMPTION AND AIR POLLUTANT EMISSIONS FROM STEAM-ELECTRIC UTILITIES, 1968

Company	Plant	Fuel Oil Consumption 10^3 Gallons		Emissions, Tons/Year				
		Residual Fuel Oil	Diesel Fuel Oil	SOx	PART.	CO	HC	NOx
Hawaiian Electric								
	Kahe	73,170	--	11,100	370	1	110	3,800
	Honolulu	37,152	--	5,600	180	1	60	1,900
	Waiau	91,583	--	13,800	460	2	150	4,800
Subtotal		201,900	--	30,500	1,010	4	320	10,500
Hilo Electric								
	Hilo*	14,859	301	3,200	80	N	40	780
Kauai Electric								
	Port Allen	--	308	5	2	N	0.5	16
Maui Electric								
	Kahului	11,311	--	2,400	60	N	18	590
Molokai Electric								
	Kaunakakai	--	1,226	22	6	N	2	64
GRAND TOTAL		228,000	1,840	36,100	1,160	4	390	12,000

* Includes other standby stations.

Because the study area consisted of the entire State, total fuel consumption figures were readily available from the Bureau of Mines.[10,11] The fuel oils were apportionned into the counties on the basis of population or manufacturing employment. Liquified petroleum gases were assumed to have the same county breakdown as listed in the Data Book.[3] Manufactured gas is only sold and distributed on Oahu. Sulfur contents of 2.7 percent for resudual fuel oil and 0.25 percent for distillate fuel oil was assumed, except where individual plant information was available.

For the island of Oahu, the air pollutant emissions from fuel combustion were apportionned onto the grids by the use of population for residential-commercial-institutional sources, and by industrial land use for industrial sources.[12]

The air pollutant emissions from the stationary combustion of fuels totals 44,000 tons of sulfur oxides, 2,000 tons of particulate matter, 60 tons of carbon monoxide, 500 tons of hydrocarbons and 16,000 tons of nitrogen oxides (Table 10). The combustion of residual fuel oil in steam-electric utilities is the predominant fuel combustion source. Emissions from distillate fuel oil, liquified petroleum gases, and manufactured gas are insignificant in comparison.

SOLID WASTES

More than 1.6 million tons of solid wastes are generated annually in the State of Hawaii. The bulk of this refuse (about 64 percent) is disposed of by means of on-site backyard burning. Table 11 indicates that only 34 percent of the solid wastes generated are collected and disposed of at central disposal sites. There are only two municipal incinerators, both located in Honolulu. Both are equipped with baffles and wet caps. The predominant form of central disposal facility is the open burning dump.

TABLE 10 AIR POLLUTANT EMISSIONS FROM THE COMBUSTION OF FUELS IN STATIONARY SOURCES, 1968 (TONS/YEAR)*

Fuel	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Distillate Fuel Oil					
Residential, Commercial, Institutional	160	70	9	9	320
Industry	120	50	7	7	250
Steam-Electric	30	10	N	3	100
Residual Fuel Oil					
Residential, Commercial, Institutional	2,470	130	12	12	410
Industry	5,000	390	22	90	2,200
Steam-Electric	36,100	1,090	4	360	11,300
Liquified Petroleum Gas					
Residential, Commercial, Institutional	1	93	2	N	570
Industry	N	4	N	N	44
Steam-Electric	--	--	--	--	--
Manufactured Gas					
Residential, Commercial, Institutional	N	11	N	N	68
Industry	N	12	N	N	140
Steam-Electric	--	--	--	--	--
GRAND TOTAL					
Residential, Commercial, Institutional	2,600	300	23	21	1,400
Industry	5,100	460	30	100	2,600
Steam-Electric	36,100	1,200	4	380	12,000

N = Negligible

* Excluding agricultural fuel combustion emissions which are included in the Agriculture Section.

TABLE 11 SOLID WASTES DISPOSAL BY COUNTY, 1968 (10^3 TONS/YEAR)

County	Total Generated	Central Disposal Sites					On-Site	
		Municipal Incineration	Open Burning Dumps	Landfills	Other	Total	Incineration	Backyard Burning
Hawaii	125	N	23	N	7	30	N	95
Honolulu	1,420	142	235	82	26	485	40	895
Kauai	48	N	18	N	N	18	N	30
Maui	95	N	30	N	N	30	N	65
STATE TOTAL	1,688	142	306	82	33	563	40	1,085
Percent of State Total	100	9	18	5	2	34	2	64

Information on the collection of solid wastes at the various sites was gathered from the Honolulu City and County Division of Refuse and from a report recently completed for the Hawaii State Department of Health.[13] Generation rates were also obtained from the report. It was assumed that 15 pounds per capita per day of solid wastes were generated from all sources in the city of Honolulu. For rural Oahu and the remaining counties, 10 pounds per capita per day was assumed to be the generation rate.

Due to the prevalence of open burning, solid wastes disposal sources are significant contributors to particulate matter, carbon monoxide, and nitrogen oxides emissions. However, much of the uncollected open burning occurs in the non-urbanized areas. Table 12 shows the county breakdown of solid wastes disposal emissions.

INDUSTRIAL PROCESS LOSSES

The State of Hawaii is notable devoid of any heavy industrial complexes with the exception of a petroleum refinery and a steel rolling mill. From an air pollution standpoint, the petroleum refinery and the mineral products industry are the most significant industrial process sources of air pollutants.

As is the case in any emission inventory, the lack of emission factors and process information for some industrial sources did not allow a complete estimation of process emissions. The industrial processes on the island of Oahu were surveyed, whereas the types of processes on the neighbor islands were considered negligible.

Two portland cement manufacturing plants collectively produce about 2 million barrels of cement annually. These plants utilize the wet process. The kilns are equipped with electrostatic precipitators and the driers are equipped with fabric baghouses.

There are two small metal foundry operations on Oahu. One utilizes a cupola with a wet cap, while the other uses an electric arc furnace.

TABLE 12 AIR POLLUTANT EMISSIONS FROM SOLID WASTES DISPOSAL 1968, (TONS/YEAR)

County	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Hawaii					
Open Burning Dump	10	180	980	350	130
Backyard Burning	50	760	4,200	1,430	530
Total	60	940	5,180	1,780	660
Honolulu					
Municipal Incineration	140	480	70	20	140
On-Site Incineration	40	180	1,200	50	50
Open Burning Dump	120	1,850	9,840	3,450	1,280
Backyard Burning	450	7,160	38,000	13,450	4,920
Total	750	9,670	49,100	16,900	6,390
Kauai					
Open Burning Dump	9	150	780	280	100
Backyard Burning	15	240	1,250	440	160
Total	24	390	2,030	720	260
Maui					
Open Burning Dump	15	240	1,270	450	170
Backyard Burning	30	520	2,740	970	350
Total	50	760	4,010	1,420	520
State Total					
Municipal Incineration	140	480	70	20	140
On-Site Incineration	40	180	1,200	50	50
Open Burning Dump	150	2,400	12,900	4,500	1,680
Backyard Burning	550	8,700	46,000	16,300	5,960
Total	900	12,000	60,000	20,900	7,800

Most of the metals used in the islands are either precast or finished. Thus, the demand for foundry products is slight.

Four sand and gravel operations process more than 3.4 million tons of aggregate annually. In addition to the handling, crushing and screening of aggregate, about 640,000 cubic yards of concrete are produced at the two plants that contain ready-mix facilities.

Two asphalt batching plants produce approximately 550,000 tons per year of asphalt. They are both equipped with cyclone collectors.

The petroleum refinery has a crude oil capacity of 35,000 barrels per day. The processes carried out are catalytic cracking, alkylation, and hydrogenation. The fluid catalytic cracking unit is equipped with a waste heat boiler that eliminates any carbon monoxide emissions.

There are a number of miscellaneous establishments in the study area that contribute to the total air pollutant emissions. These include a lime plant producing about 8,000 tons per year and controlled by a fabric baghouse, a mixed fertilizer plant, tire-recapping plants, wood-working operations, and a number of food processing plants.

Air pollutant emissions from industrial process losses on the island of Oahu amount to 6,400 tons of sulfur oxides, 4,400 tons of particulate matter, 40 tons of carbon monoxide, 1,100 tons of hydrocarbons, and 1,200 tons of nitrogen oxides annually. The emissions by the various industrial operations are presented in Table 13. The petroleum refinery is the predominant industrial process source of the gaseous pollutants, while the mineral products industry is the most significant particulate emitter.

The southwest corner of Oahu has been zoned as a heavy industrial area. Some of the industries presently there are the petroleum refinery, the steel rolling mill, and one of the cement plants. Fortunately, the tradewinds are such as to carry most of the pollutants from these sources out to sea. Only in unusual "kona weather" are these emissions carried toward the urbanized areas of Oahu.

TABLE 13 AIR POLLUTANT EMISSIONS FROM INDUSTRIAL PROCESS LOSSES ON THE ISLAND OF OAHU, 1968 (TONS/YEAR)

Source	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Cement Manufacturing	N	200	N	N	N
Metal Operations	N	80	40	N	N
Sand & Gravel Operations	N	3,400	N	N	N
Concrete Batching	N	70	N	N	N
Asphalt Batching	N	220	N	N	N
Petroleum Refining	6,400	280	N	1,070	1,150
Other	N	100	N	N	N
TOTAL	6,400	4,400	40	1,100	1,200

N = Negligible

TABLE 14 HYDROCARBON EMISSIONS FROM EVAPORATIVE LOSSES 1968 (TONS/YEAR)

County	Gasoline Storage & Handling	Industrial Solvent Evaporation	Dry Cleaning	Surface Coating	Total
Hawaii	570	410	130	270	1,400
Honolulu	4,800	4,300	1,300	2,800	13,200
Kauai	270	160	50	100	580
Maui	410	310	100	200	1,020
STATE TOTAL	6,000	5,200	1,600	3,400	16,000

EVAPORATIVE LOSSES

Hydrocarbons are emitted during the evaporation of organic solvents and liquid petroleum products used for various purposes. Four types of evaporative losses are included in this section: gasoline storage and handling, industrial solvent evaporation, dry cleaning operations, and surface coating operations. Collectively, these sources contribute 16,000 tons of hydrocarbons in the State (Table 14). This total accounts for nearly 21 percent of the total hydrocarbons emitted from all sources.

Gasoline Storage and Handling

There are four major points (excluding evaporation losses from the motor vehicle) of hydrocarbon emissiors in the storage and handling of gasoline. They are:

1. Breathing and filling losses from storage tanks.
2. Filling losses from loading tank conveyances.
3. Filling losses from loading underground storage tanks at service stations.
4. Spillage and filling losses in filling automobile gas tanks at service stations.

From 1965 data, about 1 percent of the 198 gallons of gasoline consumed in the State is lost by evaporation at one of the four emission points listed above.[14] The resulting emissions of hydrocarbons were 6,000 tons in 1968. Table 14 lists the breakdown by county.

Industrial Solvent Evaporation

The Maricopa County Health Department estimates the per capita solvent usage as 12.5 pounds per capita per year for industrial and other domestic uses. Assuming that all solvents used are eventually emitted into the atmosphere by evaporation, 5,200 tons of hydrocarbons are emitted annually.

Dry Cleaning

Los Angeles County estimates the dry cleaning use of organic solvents at 3.9 pounds per capita per year.[1] Based on this factor, about 1,600 tons per year of hydrocarbons are emitted from dry cleaning operations. Table 14 indicates the county breakdown of emissions.

Surface Coating

Organic solvents are lost from surface coating operations as a result of evaporation and vaporization during the spraying application and subsequent drying or baking. All solvents consumed are normally released to the atmosphere. Using 8.1 pounds per capita per year as the basis, 3,400 tons of hydrocarbons are emitted in the State.[15]

AGRICULTURE

Agriculture, mainly the sugar cane and pineapple industries, is an important aspect of Hawaii's economy. Hawaii raises slightly more than half the food it needs to feed its own population, plus the million or more annual visitors and members of the armed forces. Thus, Hawaii's agricultural activities include much more than the two major crops. Table 15 shows the distribution of crop acreage for five different crops.

Of the major crops raised in Hawaii, the sugar industry is the predominant source of air pollutant emissions. The pineapple industry and coffee industry do have some odor related problems, but these are localized in nature.

Three types of agricultural emissions of air pollutants were considered in this survey: the burning of sugar cane fields before harvesting; the incineration of bagasse; and the combustion of fuels for agricultural purposes.

TABLE 15 DISTRIBUTION OF CROP ACREAGE BY COUNTY, 1968 (Acres)

County	Sugar Cane	Pineapples*	Fruits & Vegetables	Coffee*	Macadamia Nuts*
Hawaii	53,000	--	2,750	5,080	4,420
Honolulu	37,800	20,400	1,760	--	100
Kauai	51,900	2,600	340	--	140
Maui	44,000	46,500	1,360	--	170
STATE TOTAL	186,700	69,500	6,210	5,080	4,830

* 1965 Data

TABLE 16 SUGAR PRODUCTION BY COUNTY, 1968

County	Number of Sugar Mills	Raw Sugar Production Tons / Year
Hawaii	10	228,000
Honolulu	4	455,000
Kauai	8	264,000
Maui	3	288,000
STATE TOTAL	25	1,235,000

Cane Field Burning

The first step in harvesting the mature cane is to set fire to the cane fields, which take about 22 to 24 months to ripen in Hawaii. The fire consumes up to 30 tons per acre of dry leaves and trash. Table 16 shows the raw sugar production by county in Hawaii. To produce this 1.2 million tons of raw sugar annually, an estimated 2.8 million tons of leaves and trash are burned before harvesting. The resultant air pollutant emissions are 24,000 tons of particulate matter, 91,000 tons of carbon monoxide, 2,900 tons of hydrocarbons, and 2,900 tons of nitrogen oxides. Sulfur oxides emissions are negligible (Table 17).

Bagasse Incineration

All the twenty-five sugar mills in the State operate on a 24 hour a day basis during the grinding season, which lasts from nine to eleven months a year. The cane is washed, crushed between high pressure rollers to extract the juice, then the juice is processed through a number of steps before ending up as raw sugar. Bagasse is the fibrous residue of the cane stalk left after the high pressure crushing operation.

Most of the factories utilize bagasse as a fuel to provide process heat and power. Some of the electricity generated is sold to the local utility companies for distribution. Some fuel oil is used as an auxiliary fuel to maintain the proper combustion characteristics. The bagasse incineration produces about 25,600 tons of particulate matter and 2,000 tons of sulfur oxides (from the auxiliary fuel). The other pollutants are insignificant.

Agricultural Fuel Combustion

From the data listed in the stationary fuel combustion section, 14.9 million gallons of diesel fuel, 2.2 million gallons of distillate fuel oil, 24 million gallons of residual fuel oil, and 800 thousand gallons of liquified petroleum gases were consumed in 1968 for agricultural purposes. Most of this fuel was used to operate farm

machinery, such as tractors, pumps, generators and harvesting equipment. Table 18 shows the breakdown of air pollutant emissions by fuel and county.

TABLE 17 AIR POLLUTANT EMISSIONS FROM AGRICULTURAL OPERATIONS, 1968

County	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Hawaii					
Bagasse Incineration	730	9,400	3	3	120
Cane Burning	N	6,800	26,000	800	800
Fuel Combustion	490	40	4	4	170
Total	1,220	16,200	26,000	810	1,090
Honolulu					
Bagasse Incineration	370	4,700	2	2	62
Cane Burning	N	4,800	19,000	600	600
Fuel Combustion	900	80	8	8	310
Total	1,270	9,580	19,000	610	970
Kauai					
Bagasse Incineration	430	5,500	2	2	70
Cane Burning	N	6,600	25,000	800	800
Fuel Combustion	150	12	2	2	50
Total	580	12,100	25,000	800	920
Maui					
Bagasse Incineration	460	6,000	2	2	80
Cane Burning	N	5,600	21,000	700	700
Fuel Combustion	2,140	250	28	28	1,050
Total	2,600	11,900	21,000	730	1,800
STATE TOTAL					
Bagasse Incineration	2,000	25,600	10	10	330
Cane Burning	N	23,800	91,000	2,900	2,900
Fuel Combustion	3,700	390	40	40	1,570
GRAND TOTAL	5,700	50,000	91,000	3,000	4,800

TABLE 18 AIR POLLUTANT EMISSIONS FROM AGRICULTURAL FUEL COMBUSTION[a] (TONS/YEAR)

County	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Hawaii					
Distillate Fuel Oil[b]	44	18	2	2	87
Residual Fuel Oil	450	24	2	2	76
LPG	N	1	N	N	6
Honolulu					
Distillate Fuel Oil	80	34	4	4	160
Residual Fuel Oil	820	44	4	4	137
LPG	N	2	N	N	11
Kauai					
Distillate Fuel Oil	13	5	1	1	25
Residual Fuel Oil	135	7	1	1	23
LPG	N	N	N	N	2
Maui					
Distillate Fuel Oil	366	152	20	20	730
Residual Fuel Oil	1,770	95	8	8	298
LPG	N	4	N	N	24
STATE TOTAL					
Distillate Fuel Oil	500	210	27	27	1,000
Residual Fuel Oil	3,200	170	15	15	530
LPG	N	7	N	N	42

a Excluding auxiliary fuel used for bagasse incineration

b Includes diesel fuel

EMISSIONS BY JURISDICTION

The previous section presented the emissions by source category and by jurisdiction. The emissions by county are summarized here in Tables 19 through 22. The relative contribution of each county to the total pollutant emissions is summarized in Table 23. The following is a brief summary of air pollutant emissions for each county.

HAWAII

The total air pollutants on the island of Hawaii amount to 4,900 tons of sulfur oxides, 18,000 tons of particulate matter, 57,000 tons of carbon monoxide, 7,700 tons of hydrocarbons, and 4,400 tons of nitrogen oxides in 1968. The major contributors are the combustion of residual fuel oil in steam-electric utilities (for sulfur oxides), motor vehicles (carbon monoxide, hydrocarbons, and nitrogen oxides), and agriculture (particulate matter, carbon monoxide, and nitrogen oxides).

HONOLULU

The City and County of Honolulu is the capital island of Hawaii. The business, finance and commerce of the islands is centered in Honolulu. The high degree of urbanization and congestion makes Oahu similar to many mainland cities. In terms of air pollutants, the same types of sources and the magnitude of emissions are found as in many metropolitan areas. With 83 percent of the population and 71 percent of the manufacturing employment in the State, the majority of air pollutant emissions in the State are attributed to Oahu. More than 82 percent of the sulfur oxides, 38 percent of the particulate matter, 66 percent of the carbon monoxide, 78 percent of the hydrocarbons, and 76 percent of the nitrogen oxides emissions in the State are emitted there. The percentage

contribution to the state totals is relatively low for particulate matter and carbon monoxide because of the agricultural activity, mainly sugar cane burning and bagasse incineration, on the other islands.

The primary sources of the 49,000 tons of sulfur oxides emissions on Oahu are the 3 power plants burning residual fuel oil. They account for about 62 percent or 30,500 tons per year. Industrial process losses and other stationary fuel combustion sources contribute an additional 13 percent and 15 percent, respectively.

Agricultural operations, solid wastes disposal and industrial process losses are the primary sources of the 27,000 tons of particulate matter. More specifically, cane field burning (18 percent), bagasse incineration (17 percent), the open burning of refuse (33 percent), and industrial process losses (16 percent) collectively account for 84 percent of the particulate matter emissions. Sand and gravel operations contribute 3,400 of the 4,400 tons attributed to industrial process losses. This excludes the dust and heavy particles that can cause local nuisances.

Motor vehicles contribute more than 70 percent or 184,000 tons of the total carbon monoxide emitted on Oahu. The open burning of refuse and the burning of cane fields, both inefficient combustion processes, account for any additional 18 percent and 7 percent, respectively.

Ninety-one percent of the 59,000 tons of hydrocarbons are emitted by motor vehicles, open burning of refuse, and evaporative losses. Motor vehicle hydrocarbon emissions of 23,800 tons (40 percent) emanate from the exhaust, the crankcase, the carburetor, and the gasoline tank. The open burning of refuse at dumps and on-site contribute 16,900 tons (28 percent) of unburnt hydrocarbons and evaporative losses account for 22 percent of the hydrocarbon emissions.

Nitrogen oxides, a fuel combustion related pollutant, is emitted primarily from motor vehicles (10,000 tons) and steam-electric utilities (10,500 tons). Collectively they account for 60 percent of the total 34,000 tons of nitrogen oxides emissions on Oahu. Solid wastes disposal contributes another 19 percent.

KAUAI

The primary sources of air pollutants on the island of Kauai are agricultural operations and motor vehicles. Collectively they account for 88 percent of the 800 tons of sulfur oxides, 96 percent of the particulate matter, 94 percent of the carbon monoxide, 63 percent of hydrocarbons, and 79 percent of the nitrogen oxides emissions on Kauai. All other sources are negligible in comparison.

MAUI

In Maui County, which includes 4 islands, annual air pollutant emissions amount to 5,400 tons of sulfur oxides, 13,000 tons of particulate matter, 43,000 tons of carbon monoxide, 5,700 tons of hydrocarbons, and 4,200 tons of nitrogen oxides. The major sources of sulfur oxides are stationary and agricultural fuel combustion. Agricultural operations contribute 92 percent of the total particulate emissions. Motor vehicles and agriculture collectively contribute 86 percent of the carbon monoxide emissions. Hydrocarbon and nitrogen oxides emissions are distributed among the various sources.

RELATIVE COUNTY CONTRIBUTION

Table 23 summarizes the relative contribution of each county to the total air pollutant emissions in the State. Naturally, Honolulu contributes the highest percentage of any pollutant. The contribution to particulate matter and carbon nomoxide emissions is low because of the agricultural operations on the neighbor islands.

TABLE 19 SUMMARY OF AIR POLLUTANT EMISSIONS IN HAWAII COUNTY
1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation	270	290	25,800	3,600	1,600
Motor Vehicles	100	170	22,700	2,900	1,300
Aircraft	N	90	3,100	660	210
Vessels	170	25	42	23	60
Fuel Combustion in Stationary Sources	3,400	130	4	43	1,050
Residential, Commercial Institutional	180	40	3	2	230
Industry	13	6	1	1	40
Steam-Electric Utility	3,200	80	N	40	780
Solid Wastes Disposal	60	940	5,200	1,800	660
Open Burning	60	940	5,200	1,800	660
Incineration	N	N	N	N	N
Industrial Process Losses	N	N	N	N	N
Evaporative Losses	N	N	N	1,400	N
Agriculture	1,200	16,200	26,000	810	1,100
TOTAL	4,900	18,000	57,000	7,700	4,400

TABLE 20 SUMMARY OF AIR POLLUTANT EMISSIONS IN THE CITY AND COUNTY OF HONOLULU, 1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation	2,500	1,900	194,000	26,200	11,400
Motor Vehicles	760	1,100	184,000	23,800	10,000
Aircraft	N	600	9,800	2,200	870
Vessels	1,760	220	280	190	560
Fuel Combustion in Stationary Sources	38,000	1,700	50	430	14,000
Residential, Commercial, Institutional	2,300	220	19	18	950
Industry	5,100	440	26	94	2,500
Steam-Electric Utility	30,500	1,010	4	320	10,500
Solid Wastes Disposal	750	9,700	49,000	17,000	6,400
Open Burning	570	9,000	47,800	16,900	6,200
Incineration	180	660	1,300	70	190
Industrial Process Losses	6,400	4,400	40	1,100	1,200
Evaporative Losses	N	N	N	13,200	N
Agriculture	1,300	9,600	19,000	610	970
TOTAL	49,000	27,000	262,000	59,000	34,000

TABLE 21 SUMMARY OF AIR POLLUTANT EMISSIONS IN KAUAI COUNTY
1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation	120	90	10,500	1,400	620
Motor Vehicles	50	70	10,500	1,350	580
Aircraft	N	13	36	39	18
Vessels	70	7	9	6	20
Fuel Combustion in Stationary Sources	80	23	1	2	130
Residential, Commercial, Institutional	70	17	N	N	90
Industry	9	4	1	1	23
Steam-Electric Utility	5	2	N	1	16
Solid Wastes Disposal	20	390	2,000	720	260
Open Burning	20	390	2,000	720	260
Incineration	N	N	N	N	N
Industrial Process Losses	N	N	N	N	N
Evaporative Losses	N	N	N	580	N
Agriculture	580	12,100	25,000	800	920
TOTAL	800	12,600	38,000	3,500	1,900

TABLE 22 SUMMARY OF AIR POLLUTANT EMISSIONS IN MAUI COUNTY
1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation	180	230	17,700	2,500	1,070
Motor Vehicles	70	110	15,900	2,100	880
Aircraft	N	100	1,800	380	150
Vessels	110	17	21	15	40
Fuel Combustion in Stationary Sources	2,600	100	2	22	800
Residential, Commercial Institutional	140	23	1	1	120
Industry	14	7	1	1	35
Steam-Electric Utility	2,400	70	N	20	650
Solid Wastes Disposal	50	760	4,000	1,400	520
Open Burning	50	760	4,000	1,400	520
Incineration	N	N	N	N	N
Industrial Process Losses	N	N	N	N	N
Evaporative Losses	N	N	N	1,020	N
Agriculture	2,600	12,000	21,000	730	1,800
TOTAL	5,400	13,000	43,000	5,700	4,200

TABLE 23 RELATIVE CONTRIBUTION OF EACH COUNTY TO TOTAL AIR POLLUTANT EMISSIONS, 1968 (Percent)

County	Population	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Hawaii	8	8	26	14	10	10
Honolulu	83	82	38	66	78	76
Kauai	3	1	18	9	5	4
Maui	6	9	18	11	7	10
TOTAL	100	100	100	100	100	100

EMISSIONS BY GRID

For the purpose of defining the geographical variation of air pollutant emissions on the island of Oahu, the resulting emissions were apportioned on the grid coordinate system. The emissions were divided into two source subgroups—point and area sources—as explained in the Preface. Twenty-eight point sources are identified individually with respect to location and magnitude of emissions. Each of these point sources emits more than 0.2 tons per day of any individual pollutant.

CONTRIBUTION OF POINT SOURCES

Collectively, the twenty-eight point sources account for 87 percent of sulfur oxides, 46 percent of particulate matter, 4 percent of carbon monoxide, 8 percent of hydrocarbons, and 41 percent of nitrogen oxides emissions on the island of Oahu. Figure 5 shows the location of all point sources on the island. The percent contribution to carbon monoxide emissions is low because motor vehicles and much of the on-site open burning, which are area sources, contribute 98 percent of carbon monoxide emissions. Similarly, the contribution of point sources to total hydrocarbon emissions is low since motor vehicles, evaporative losses, and on-site open burning are the major contributors. Table 24 summarizes the air pollutant emissions from point sources on Oahu. Most of the seasonal variations in point source emissions are negligible.

The emissions from area sources have been added to that for point sources to obtain total emissions by grid. Table 25 summarizes the total air pollutant emissions by grid. The emissions are presented for an annual average day, an average winter day (December, January, February), and an average summer day (June, July, August). The annual average emission rates were obtained by dividing yearly totals by 365 days per year. Seasonal averages were calculated by the use of motor vehicle traffic activity factors and monthly fuel use information. Other sources were assumed to be constant throughout the year.

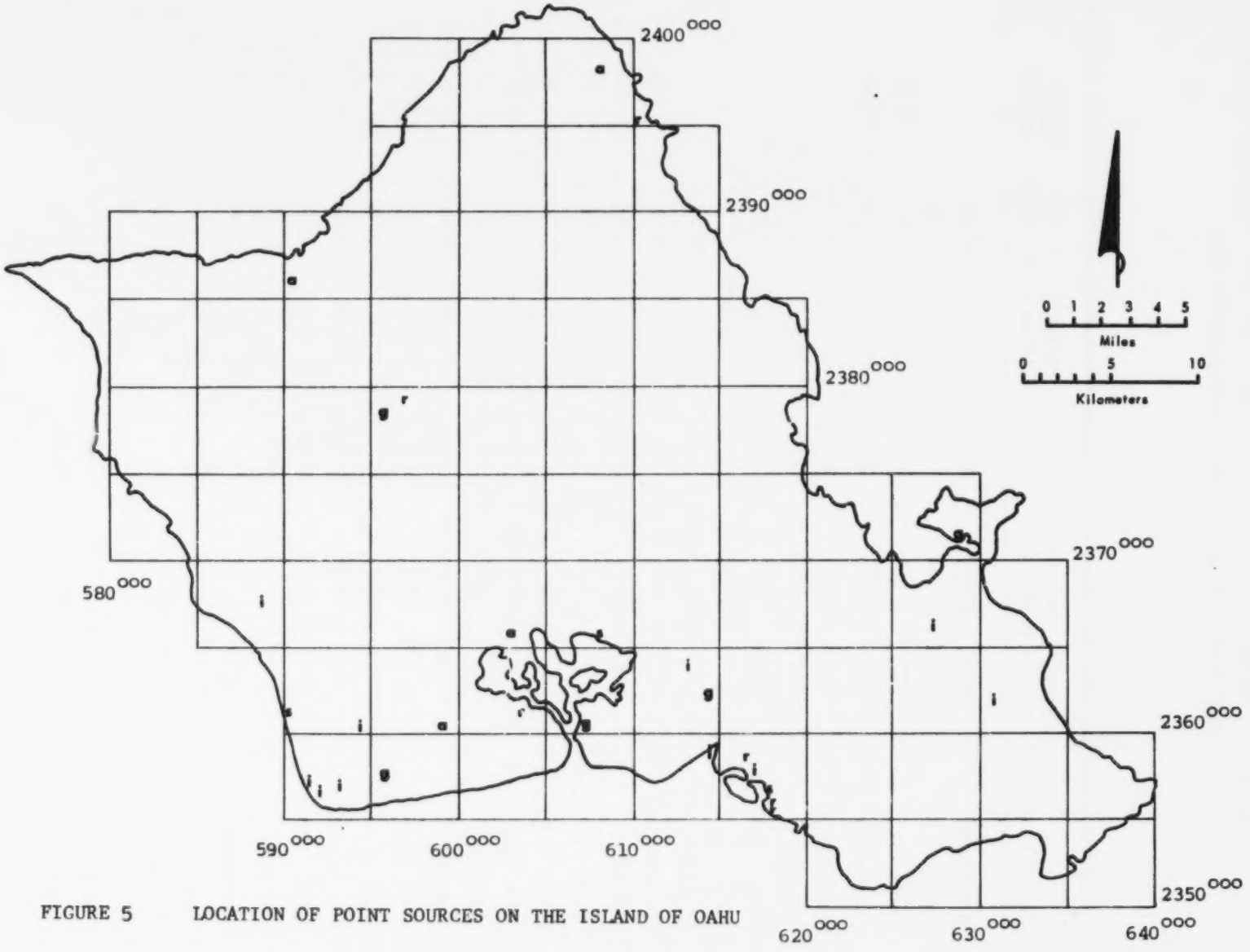

FIGURE 5 LOCATION OF POINT SOURCES ON THE ISLAND OF OAHU

TABLE 24 SUMMARY OF AIR POLLUTANT EMISSIONS FROM POINT SOURCES ON THE ISLAND OF OAHU, 1968 (TONS/AVERAGE DAY)

Source	Grid	Easting (100 m.)	Northing (100 m.)	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Industry	5	5922	23560	0.0	0.27	0.00	0.00	0.00
Industry	5	5920	23571	17.4	0.75	0.00	2.92	3.14
Industry	5	5926	23559	0.0	0.22	0.03	0.00	0.00
Government	6	5960	23575	0.0	0.56	3.02	1.06	0.39
Industry	9	6149	23591	0.0	0.49	0.00	0.00	0.00
Industry	10	6173	23580	13.5	0.72	0.06	0.06	2.27
Power Plant	10	6178	23568	15.3	0.50	0.00	0.16	5.29
Open Dump	10	6178	23553	0.0	0.17	0.92	0.32	0.12
Incinerator	10	6169	23587	0.1	0.67	0.09	0.02	0.19
Incinerator	10	6178	23555	0.1	0.64	0.09	0.02	0.18
Industry	15	5947	236 2	0.0	2.73	0.00	0.00	0.00
Power Plant	15	5900	23620	30.2	1.00	0.00	0.32	10.42
Agriculture	16	5996	236 3	0.2	3.33	0.00	0.00	0.04
Open Dump	17	6028	23647	0.2	3.39	18.03	6.36	2.33
Government	18	6080	23610	0.0	0.05	1.38	0.11	0.01
Industry	19	6130	23645	0.0	3.87	0.00	0.00	0.00
Institution	19	6147	23625	0.5	0.04	0.04	0.00	0.09
Industry	23	6307	23618	0.0	0.82	0.00	0.00	0.00
Agriculture	27	6025	23655	0.3	4.15	0.00	0.00	0.00
Power Plant	28	6078	23656	37.9	1.25	0.00	0.40	13.04
Industry	32	6275	23670	0.0	1.93	0.00	0.00	0.00
Government	43	6290	23720	0.0	0.48	2.56	0.90	0.33
Government	47	5960	23780	0.1	0.14	0.74	0.25	0.11
Open Dump	47	5971	23792	0.0	0.16	0.87	0.30	0.11
Agriculture	62	5903	23861	0.3	4.21	0.00	0.00	0.05
Open Dump	70	6102	23952	0.0	0.14	0.75	0.26	0.09
Agriculture	73	6086	23978	0.1	1.19	0.00	0.00	0.02
Industry	74	5880	23678	0.0	0.27	0.00	0.00	0.00

TABLE 25 SUMMARY OF AIR POLLUTANT EMISSIONS BY GRID ON THE ISLAND OF OAHU, 1968 (TONS/DAY

Grid	Area (sq. km.)	SOx S	SOx W	SOx A	PART. S	PART. W	PART. A	CO S	CO W	CO A	HC S	HC W	HC A	NOx S	NOx W	NOx A
1	14	0.2	0.2	0.2	0.3	0.3	0.3	47.9	53.6	51.0	6.1	6.8	6.5	2.6	2.9	2.7
2	10	0.1	0.1	0.1	0.1	0.1	0.1	15.1	16.9	16.1	1.9	2.1	2.0	0.8	0.9	0.9
3	8	0.0	0.0	0.0	0.0	0.0	0.0	6.5	7.2	6.9	0.8	0.9	0.9	0.3	0.4	0.4
4	4	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.0	0.9	0.2	0.2	0.2	0.1	0.1	0.1
5	17	18.0	18.0	18.0	1.3	1.3	1.3	0.6	0.6	0.6	3.2	3.2	3.2	3.4	3.4	3.4
6	20	0.1	0.1	0.1	0.7	0.7	0.7	5.4	5.6	5.5	1.8	1.8	1.8	0.6	0.7	0.6
7	15	0.0	0.1	0.1	0.5	0.5	0.5	6.3	6.8	6.6	1.3	1.3	1.3	0.4	0.5	0.5
8	10	0.3	0.3	0.3	0.2	0.2	0.2	1.5	1.6	1.6	0.6	0.6	0.6	0.2	0.2	0.2
9	10	0.5	0.6	0.6	2.3	2.3	2.3	37.8	39.1	38.5	7.7	7.8	7.8	3.2	3.2	3.2
10	22	33.8	31.0	33.2	7.8	7.9	7.9	124.5	136.4	131.0	28.1	29.6	28.9	17.5	17.3	17.8
11	25	0.5	1.6	1.6	3.3	3.5	3.5	81.0	88.7	85.2	19.0	20.0	19.5	5.5	6.4	6.2
12	25	0.0	0.2	0.2	0.5	0.5	0.5	6.1	6.5	6.3	2.2	2.2	2.2	0.5	0.6	0.6
13	25	0.0	0.0	0.0	0.1	0.1	0.1	1.2	1.3	1.2	0.4	0.4	0.4	0.1	0.1	0.1
14	16	0.0	0.1	0.1	0.2	0.2	0.2	3.3	3.6	3.5	1.0	1.0	1.0	0.3	0.3	0.3
15	25	30.7	30.8	30.3	3.8	3.8	3.8	6.5	7.2	6.9	1.2	1.3	1.3	11.0	11.0	10.9
16	25	0.3	0.4	0.4	4.8	4.8	4.8	12.1	12.8	12.5	1.5	1.6	1.6	0.7	0.7	0.7
17	25	0.4	0.5	0.5	4.4	4.4	4.4	27.7	28.4	28.1	8.1	8.2	8.2	2.9	3.0	3.0
18	25	1.6	1.7	1.7	0.5	0.5	0.5	12.8	14.0	13.5	2.3	2.5	2.4	1.1	1.2	1.2
19	25	0.7	1.1	1.1	5.2	5.3	5.2	32.1	35.3	33.8	7.0	7.4	7.2	2.3	2.6	2.5
20	25	0.2	0.7	0.7	1.7	1.8	1.8	29.7	32.3	31.1	8.0	8.3	8.2	2.2	2.5	2.5
21	25	0.0	0.1	0.1	0.1	0.1	0.1	4.2	4.6	4.4	0.8	0.8	0.8	0.3	0.3	0.3
22	25	0.1	0.1	0.1	0.2	0.2	0.2	11.3	12.5	11.9	1.9	2.1	2.0	0.7	0.8	0.7

TABLE 25 SUMMARY OF AIR POLLUTANT EMISSIONS BY GRID (cont.)

Grid	Area (sq. km.)	SOx			PART.			CO			HC			NOx		
		S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
23	20	0.0	0.2	0.2	1.2	1.2	1.2	6.3	6.8	6.6	1.9	1.9	1.9	0.5	0.6	0.6
24	21	0.1	0.2	0.2	0.7	0.7	0.7	8.0	8.7	8.4	2.1	2.2	2.2	0.6	0.7	0.7
25	25	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.1	0.1	0.1	0.0	0.0	0.0
26	25	0.0	0.0	0.0	0.9	0.9	0.9	3.8	3.8	3.8	0.3	0.3	0.3	0.2	0.2	0.2
27	25	0.4	0.7	0.7	6.3	6.3	6.3	19.3	20.5	20.0	3.8	3.9	3.9	1.2	1.4	1.4
28	25	38.6	39.1	38.5	3.1	3.2	3.1	28.7	31.1	30.0	7.2	7.5	7.4	15.2	15.5	15.3
29	25	0.0	0.2	0.2	0.8	0.8	0.8	6.9	7.2	7.1	1.9	1.9	1.9	0.5	0.6	0.6
30	25	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
31	25	0.1	0.4	0.4	0.8	0.8	0.8	15.8	17.2	16.5	4.1	4.3	4.2	1.1	1.3	1.3
32	22	0.1	0.6	0.5	3.1	3.2	3.2	20.4	22.1	21.4	5.8	6.0	5.9	1.5	1.8	1.8
33	18	0.1	0.2	0.2	0.5	0.5	0.5	8.2	8.9	8.6	2.4	2.5	2.4	0.6	0.7	0.7
34	11	0.0	0.1	0.1	0.3	0.3	0.3	5.1	5.5	5.4	1.5	1.6	1.5	0.4	0.5	0.5
35	25	0.0	0.1	0.1	0.2	0.2	0.2	2.0	2.2	2.1	0.7	0.7	0.7	0.2	0.2	0.2
36	25	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.1	0.1	0.1	0.0	0.0	0.0
37	25	0.0	0.0	0.0	0.1	0.1	0.1	0.9	0.9	0.9	0.3	0.3	0.3	0.1	0.1	0.1
38	25	0.0	0.1	0.1	0.2	0.2	0.2	6.0	6.7	6.4	1.2	1.3	1.2	0.4	0.4	0.4
39	25	0.0	0.0	0.0	0.1	0.1	0.1	0.8	0.9	0.8	0.3	0.3	0.3	0.1	0.1	0.1
40	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	25	0.0	0.1	0.1	0.2	0.2	0.2	2.1	2.3	2.2	0.8	0.8	0.8	0.2	0.2	0.2
42	15	0.0	0.1	0.1	0.2	0.2	0.2	4.3	4.7	4.6	1.1	1.2	1.2	0.3	0.4	0.4
43	13	0.2	0.3	0.3	0.7	0.7	0.7	4.8	4.9	4.8	1.7	1.7	1.7	0.6	0.6	0.6
44	25	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.2	0.2	0.2	0.1	0.1	0.1
45	25	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0

TABLE 25 SUMMARY OF EMISSIONS BY GRID (cont.)

Grid	Area (sq. km.)	SOx			PART.			CO			HC			NOx		
		S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
46	25	0.0	0.0	0.0	0.1	0.1	0.1	0.8	0.9	0.9	0.3	0.3	0.3	0.1	0.1	0.1
47	25	0.2	0.4	0.4	0.9	0.9	0.9	12.8	13.8	13.3	3.5	3.6	3.5	1.0	1.2	1.1
48	25	0.1	0.3	0.3	0.6	0.7	0.7	10.6	11.5	11.1	3.1	3.2	3.2	0.8	1.0	0.9
49	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	21	0.0	0.1	0.1	0.2	0.2	0.2	2.6	2.8	2.7	0.8	0.8	0.8	0.2	0.2	0.2
52	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	25	0.0	0.0	0.0	0.6	0.6	0.6	2.2	2.2	2.2	0.1	0.1	0.1	0.1	0.1	0.1
54	25	0.0	0.0	0.0	1.1	1.1	1.1	6.1	6.3	6.2	0.4	0.4	0.4	0.2	0.2	0.2
55	25	0.0	0.0	0.0	0.4	0.4	0.4	2.2	2.3	2.3	0.2	0.2	0.2	0.1	0.1	0.1
56	25	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0
57	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
58	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
59	22	0.0	0.0	0.0	0.1	0.1	0.1	2.0	2.2	2.1	0.4	0.4	0.4	0.1	0.1	0.1
60	10	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0
61	10	0.0	0.0	0.0	0.2	0.3	0.2	1.6	1.7	1.7	0.3	0.3	0.3	0.1	0.1	0.1
62	20	0.4	0.4	0.4	5.2	5.2	5.2	7.6	8.0	7.9	1.3	1.3	1.3	0.5	0.5	0.5
63	25	0.0	0.0	0.0	1.9	1.9	1.9	7.5	7.5	7.5	0.2	0.2	0.2	0.2	0.2	0.2
64	25	0.0	0.0	0.0	0.5	0.5	0.5	1.9	1.9	1.9	0.1	0.1	0.1	0.1	0.1	0.1
65	25	.0.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
66	23	0.0	0.0	0.0	0.1	0.1	0.1	1.2	1.3	1.3	0.3	0.3	0.3	0.1	0.1	0.1
67	22	0.0	0.0	0.0	0.8	0.8	0.8	3.7	3.8	3.8	0.2	0.2	0.2	0.1	0.2	0.2

TABLE 25 SUMMARY OF EMISSIONS BY GRID (cont.)

Grid	Area (sq. km.)	SOx			PART.			CO			HC			NOx		
		S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
68	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
69	25	0.0	0.0	0.0	0.3	0.3	0.3	1.2	1.2	1.2	0.1	0.1	0.1	0.0	0.0	0.0
70	9	0.0	0.1	0.1	0.6	0.6	0.6	4.0	4.2	4.1	0.9	0.9	0.9	0.3	0.3	0.3
71	6	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.1	0.1	0.1	0.0	0.0	0.0
72	24	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.7	0.6	0.1	0.1	0.1	0.0	0.0	0.0
73	22	0.1	0.2	0.2	2.4	2.4	2.4	6.5	6.7	6.6	0.7	0.7	0.7	0.3	0.3	0.3

EMISSION DENSITIES

In order to provide a visual representation of the emissions of pollutants by grids, emission density maps have been prepared for the five surveyed pollutants. Figures 6 through 10 show the variation in emission densities for the respective grids. Referring back to Figure 3, which shows the variation in population density on Oahu, the emission densities generally follow the pattern of urbanization. This is especially true for carbon monoxide and hydrocarbons which are more population oriented than the other three pollutants.

For sulfur oxides emissions, the grids with the highest emission densities are grids 5, 10, 15, and 28. Three of these grids have a power plant in them and the fourth grid contains the petroleum refinery. Particulate matter emissions are highest in grids 10, 27, and 62. As shown on Figure 5, grid 10 has the largest number of point sources, while grids 27 and 62 contain sugar mills and cane field burning operations. Similar to the sulfur oxides emission pattern, nitrogen oxides emissions are also highest in the three grids that contain the power plants.

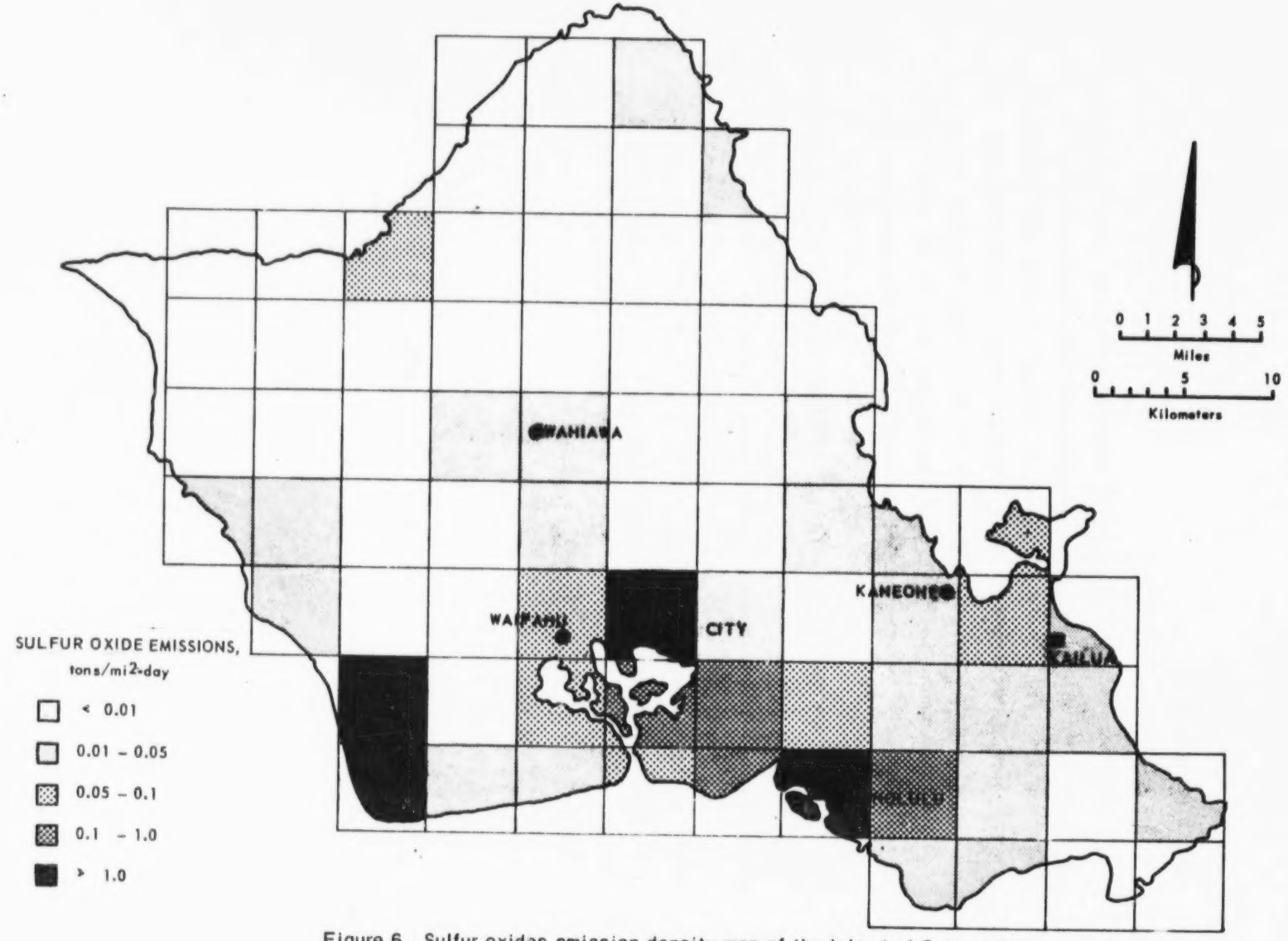

Figure 6. Sulfur oxides emission density map of the Island of Oahu, 1968.

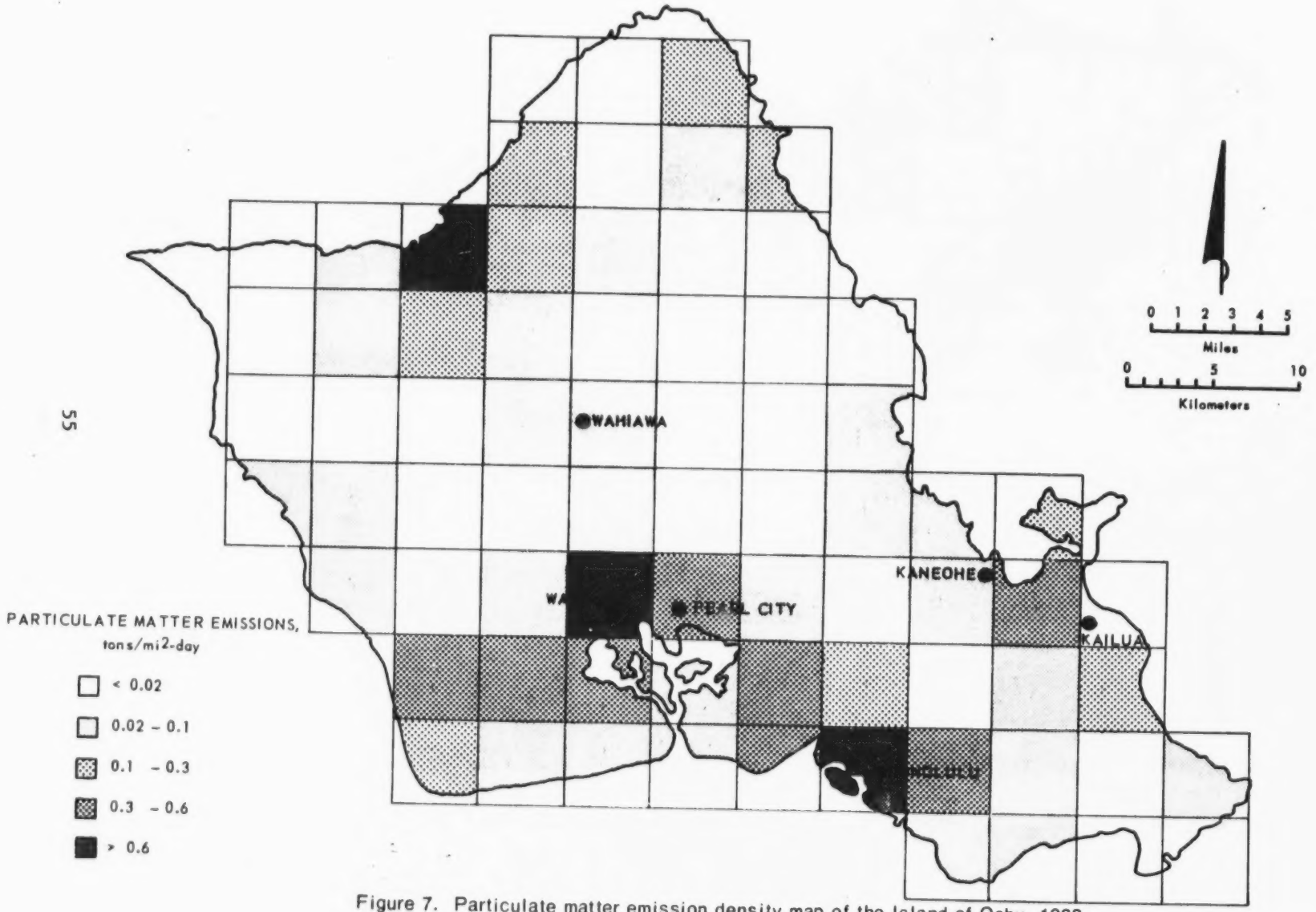

Figure 7. Particulate matter emission density map of the Island of Oahu, 1968.

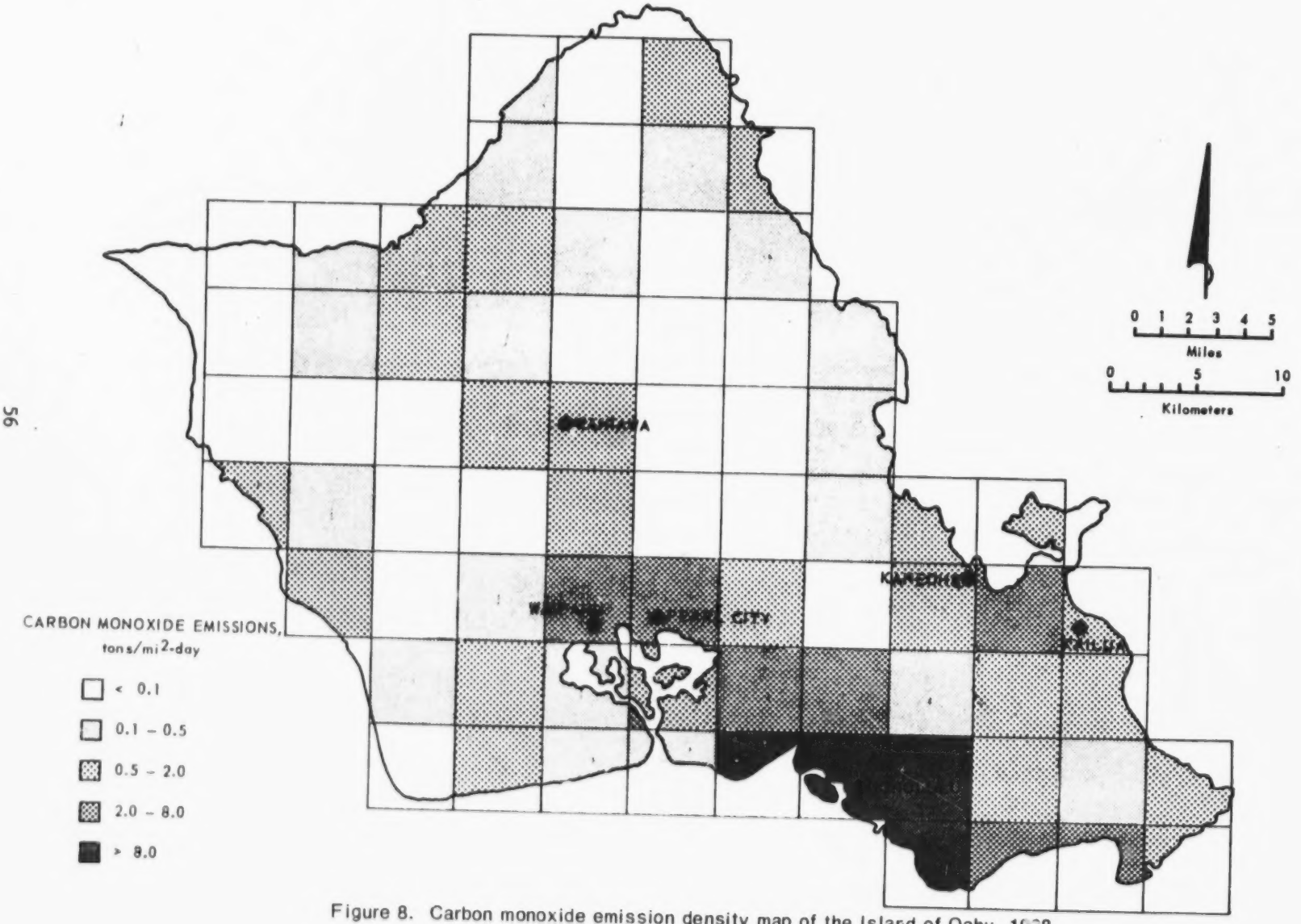

Figure 8. Carbon monoxide emission density map of the Island of Oahu, 1968.

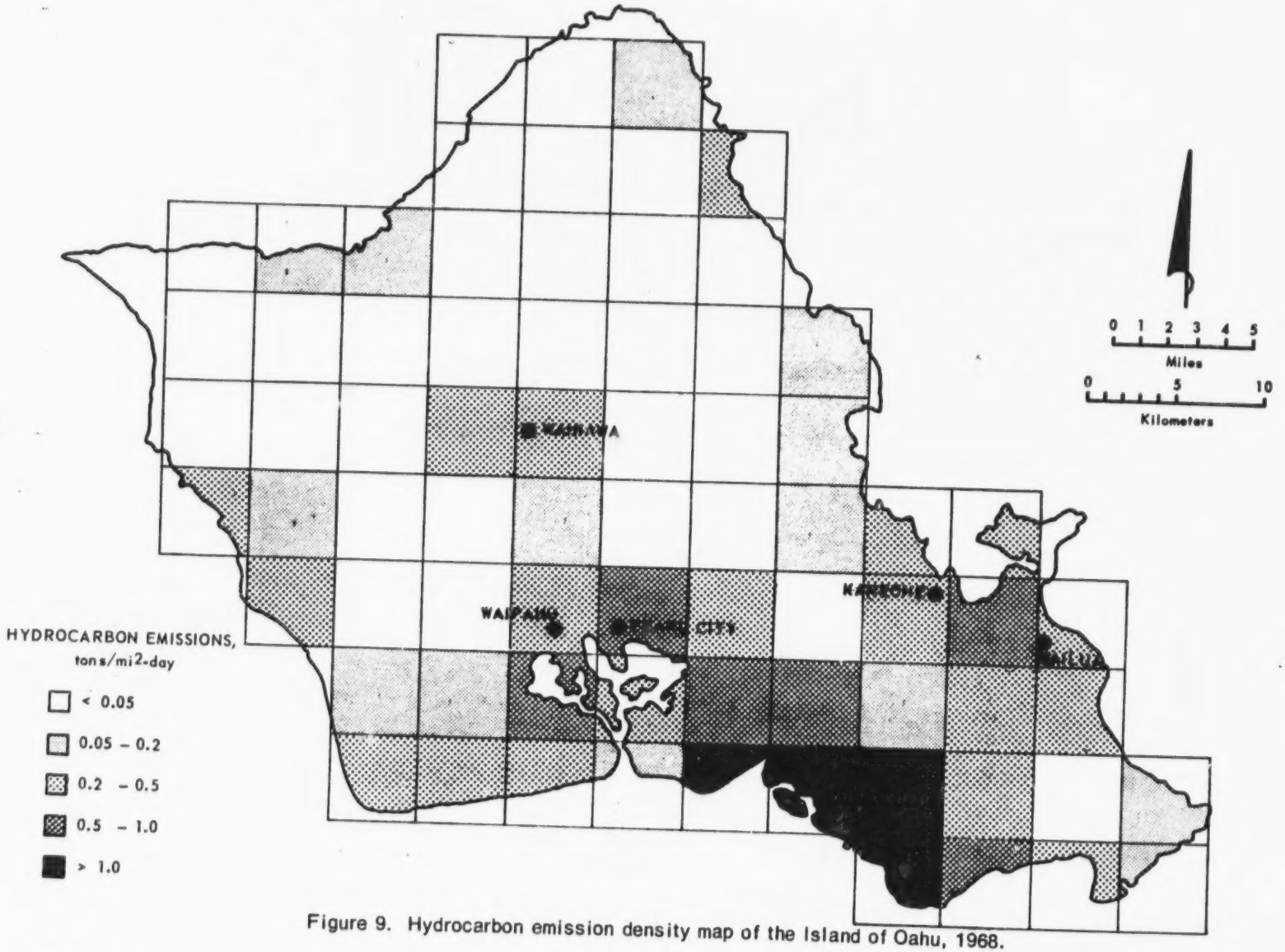

Figure 9. Hydrocarbon emission density map of the Island of Oahu, 1968.

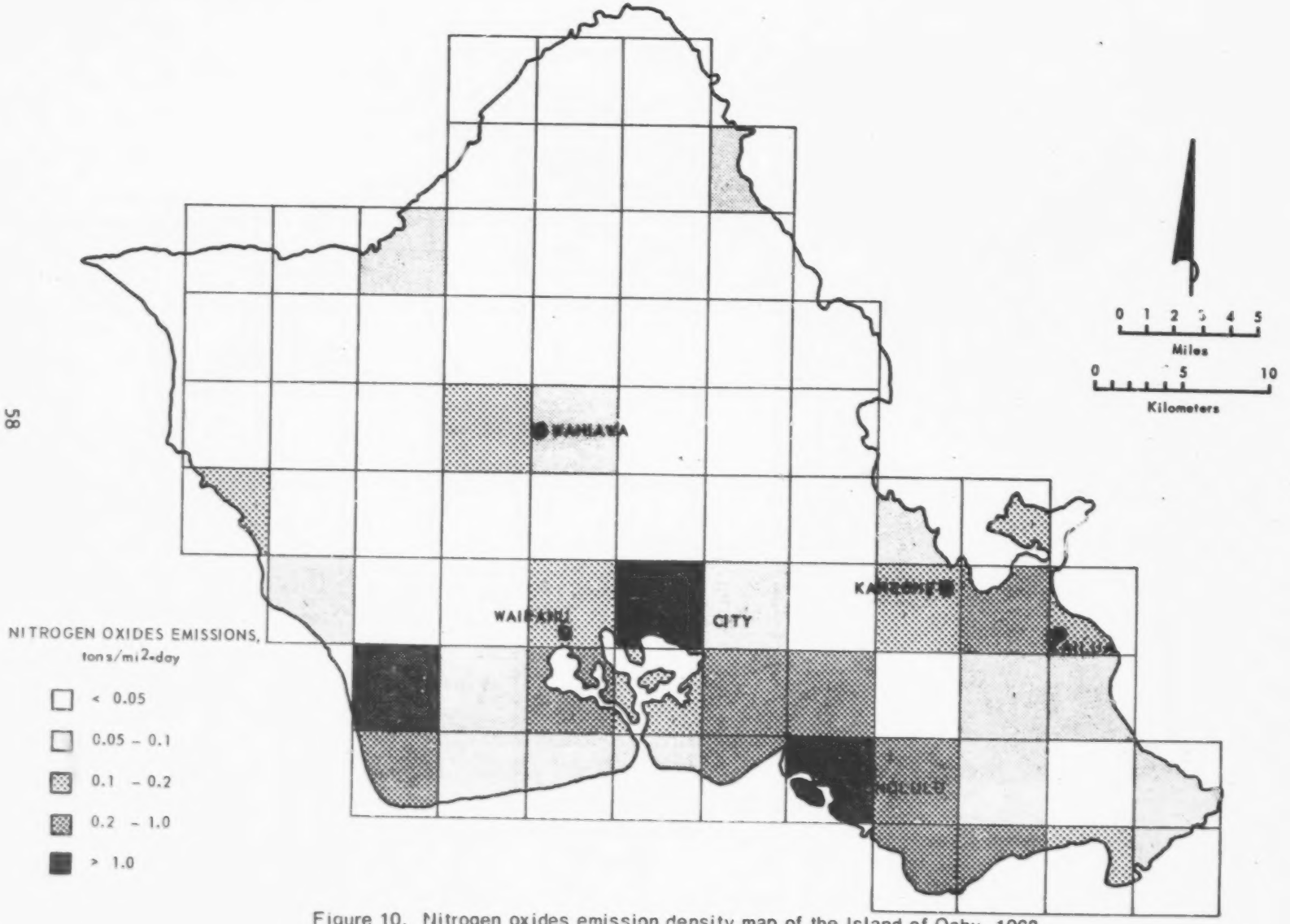

Figure 10. Nitrogen oxides emission density map of the Island of Oahu, 1968.

REFERENCES

1. Ozolins, G. and Smith, R., Rapid Survey Technique for Estimating Community Air Pollution, USDHEW, PHS, October, 1966.

2. Duprey, R.L., Compilation of Air Pollutant Emission Factors, USDHEW, PHS, 1968.

3. The State of Hawaii Data Book, Hawaii State Department of Planning and Economic Development, 1968.

4. Local Climatological Data, Honolulu, Hawaii, United States Department of Commerce, ESSA.

5. Hawaii State Department of Transportation, Highway Division, Highway Planning Section.

6. Hawaii State Department of Transportation, Oahu Transportation Study.

7. Airport Activity Statistics of Certified Route Carriers, Federal Aviation Administration, 1968.

8. FAA Air Traffic Activity, Federal Aviation Administration, March, 1969.

9. Hawaii State Division of Taxation, Tax Research and Planning

10. Fuel Oil Shipments Annual, United States Department of Interior, Bureau of Mines, September 17, 1969.

11. Shipments of Liquified Petroleum Gases and Ethane in 1968, Unites States Department of Interior, Bureau of Mines, October 13, 1969.

12. Oahu Transportation Study, 1967, Volume I.

13. The Hawaii State Plan for Solid Waste Disposal, Preliminary Draft, University of Hawaii, School of Public Health, June 30, 1969.

14. Highway Statistics/1965, Unites States Department of Transportation, Bureau of Public Roads, 1966.

15. Maricopa County Emission Inventory, Maricopa County Health Department, 1968.

16. Hawaiian Sugar Planter's Association, Personal communication to Air Sanitation Branch, Hawaii State Department of Health.

OTHER REFERENCES

1. Estimated DeFacto and Resident Population and Dwelling Units of Oahu Census Tracts, July 1, 1968, Hawaii State Department of Health, Research and Statistics Office.

2. Oahu Transportation Study, Volume I - III, Sponsoring Agencies--State of Hawaii, City and County of Honolulu, United States Department of Housing and Urban Development, Unites States Department of Transportation, 1967.